THE SPECTRUM OF THE RING NEBULA IN *LYRA.*

By Keivin Burns.

At the suggestion of Director Campbell the Ring Nebula in *Lyra* was observed with the slitless spectrograph* on the Crossley reflector, in order to determine the spectral type of the central star. As the observations were not made until early November, the plates were obtained far from the meridian, and the length of exposure had to be limited to two and one-half hours. For this reason some points that might have been cleared up by a longer exposure at higher altitudes still remain in doubt. Three satisfactory exposures were secured—one of two and one-half hours on an extra rapid Seed's *27*, one of fifteen minutes on a Seed's *23*, and one of two hours on a Cramer Crown stained† with the Wallace three-dye stain. This plate was used twenty-one days after staining, and was 50 per cent faster in the red than a freshly stained plate out of the same box. On the Seed's *27* plate several spectra of stars of the fifteenth magnitude are plainly seen.

The optical parts of this spectrograph are of quartz. The instrument is inserted in the place of the plateholder which is used in direct photographs. A double concave lens, inserted in the converging beam from the mirror, renders it parallel. The beam then passes through a 50° prism, and the light is brought to a focus by a double convex lens, whose ratio of aperture to focal length is the same as that of the mirror, one to six. Thus each ray of monochromatic light gives an image of the object photographed which is the same size as that obtained in direct photography. The aperture of the lenses and prism is one inch.

The length of spectrum from λ 656 to λ 373 is only 3.3^{mm}. The width of the image of the ring is 1.6^{mm} in declination. The spectrum extends in declination, which is not quite the shortest way of the ellipse.

The intensity of the continuous spectrum of the central star is indicated in Table I. That star in the neighborhood of the

*Palmer, *Lick Observatory Bulletin*, **2**, 46.

†Campbell, *Lick Observatory Bulletin*, **5**, 149.

nebula whose spectrum is nearest in intensity to that of the nebular star, in one of the four regions of spectrum, is indicated in column 2. The third column contains the visual magnitude of each star on the Harvard scale. Star *d* was observed with the wedge photometer, and the magnitudes of the others were obtained from a series of photographs taken on stained plates, using a color screen. The types of the comparison stars were estimated by means of the relative intensities of different regions of spectrum. Each spectrum was compared with stellar spectra of known type. The absorption lines were not distinct enough to show the type of the spectra in the *Lyra* field. The stars are lettered on the lantern slides.* The spectral intensities have been somewhat altered by reproduction. It is to be remembered that the presence of the bright rings greatly interferes with the accuracy of estimating the intensity of the spectrum of the central star.

TABLE I.

λ	Star.	Mag.	Type.
580 to 660	= *a*	14.2	A or F
430 to 480	= or br. *b*	13.8	F
370	$0^m.2$ br. *c*	12.8	A
330	= *d*	12.4	F

The central star is relatively stronger in the ultra violet than the bluest of the many *Orion* type stars whose spectra have been photographed with this spectrograph. KEELER† and others have commented on the great actinic power of this star. However, there is not the great difference between the visual and photographic magnitudes which has sometimes been thought to exist. Professor BARNARD‡ points out the difficulty of observing this star, due to its position in the center of the nebula. It has been estimated to be 15.4 magnitude by BURNHAM, and 15.5 or 16.0 by BARNARD. In the green I find it to be as bright as a fourteenth magnitude F type star. By means of direct photographs taken on stained plates through a yellow filter, I find the visual magnitude of the central star to be 14.1 and that of the second star inside the ring to be 14.7. On ordinary plates the magnitudes are found to be 13.2 and 14.5, respec-

*Shown at the meeting of the Society held in Berkeley on January 28th.

†*Astrophysical Journal*, **10**, 193.

‡*Monthly Notices*, **60**, 245.

tively. If isolated, both of these stars would be easy objects for moderately large telescopes. The spectra of the two stars are unfortunately superimposed on my spectrograms. The spectrum of the central star is entirely similar to those of the central stars or condensations in the nebulæ N. G. C. 6572, 7009, and B. D. — 12.1172. This must dispel any possible doubt that the central star is connected with the nebula. The continuous spectra of these nebulæ are remarkably similar, although the relative intensities of the various bright lines are not in the least the same in any two of them. Nor does any one of them resemble the Ring Nebula in this respect. I find no bright line or maximum in the continuous spectrum of the central star. No absorption lines are certainly visible. Fine absorption lines are not to be expected, as only the very broad ones show in other stars on the plate.

The following lines were observed in the nebula; so far as I am aware D_3 has not been observed in this nebula before:—

TABLE II.

λ	Intensity ordinary.	Intensity stained.	Extent long exposure, E. and W.	Extent long exposure, N. E. and S.W.	Extent short exposure, N. E. and S.W.	Substance.
345	2	Visible?	..	..	..	.....
373	100	50	81″	57″	56″	.....
387	10	4	76	..	..	Nebular
397	2	1	..	..	..	He
410	2	1	..	..	..	Hδ
434	2	1	..	..	..	Hγ
469	Trace	Visible?	..	..	..	.....
486	Visible?	..	..	..	..	Hβ
496 } 510 }	40	50	76	56	32	{ Chief Nebular
588	..	Trace	..	..	..	He
656	..	16	81	..	..	Hα

The wave-lengths were found by comparison with plates of N. G. C. 6572 and 7027. The lines were assumed to be the same as those with which they seemed to agree most closely on the plate mentioned, and may therefore be in error by quite a bit. Column 2 contains an estimate of the relative intensities of the lines on the ordinary plate; column 3 contains the same for the stained plate; column 4 gives the extent of the image east and west, in which direction there is no widening of the

image due to lack of homogeneity in the light forming the image. The fifth column gives the extent northeast and southwest, in which direction the nebular image is increased 4″, due to the chief nebular lines giving a single image. The sixth column gives the extent northeast and southwest on the Seed's 23 plate, and a comparison with the fifth column shows the difference in extent in a long and short exposure, and consequent difference in relative intensity of the inner and outer parts of the nebula as pictured in the light of the wave-lengths in question. MAX WOLF* finds rings of four different sizes—373 largest, next the nebular rings, then the rings of the hydrogen series, and finally the 469 ring smallest. Only four rings on the Mount Hamilton plates have the appearance of being recorded to their full extent; these are 373, 387, 496-510, and 656. Hα and 373 are extactly the same size and are identical in numerous small details. Also the relative intensities of all parts appear to be the same throughout. Hβ is too close to the chief nebular line to be distinctly seen. The other hydrogen lines are quite faint. They are not isolated north and south, so cannot be measured in that co-ordinate. They do not extend so far east and west as the Hα ring, due no doubt to the fact that the east and west ends of the nebula are not so intense as the rest of the outside of the ring. As far as they extend, the other hydrogen lines seem to be the same size and pattern as Hα, and a sufficiently long exposure would no doubt show identical images in the light of all the hydrogen lines.

The D_3 line, λ 588, is only a trace, as is also λ 469.

The chief nebular lines are not separated at all; consequently the ring is widened in declination. The line 387 gives a ring of the same width in right ascension as that formed by the chief nebular lines. These rings are smaller than those corresponding to λ 656 and λ 373. On the Seed's 23 plate the empty space within the 373 ring is nearly the diameter of the outside of the chief nebular ring. Further exposure extends this latter ring outward, but it does not attain the size of the 373 ring with the longest exposure possible at the time these observations were made. Increasing the exposure does not extend the 373 ring outward, except on the east and west ends, as the outside of the

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656 or 373 ring is the most intense part of the image. Detail is added to the inner parts of these latter rings by increasing the exposure. All the rings seem to have the same internal diameter. Since the spectrum extends in declination and the images overlap, it is impossible to tell whether the two sets of rings are centered the same north and south. The center of the nebular image seems farther west than that of the hydrogen image, but this may be an exposure effect. It is entirely possible that a more intense image in the light of the nebular lines would be equal in extent to the hydrogen image. It cannot be determined from these plates whether or not the detail is the same in the two sets of rings, but it is very evident that the intensities are entirely different, as the most intense part of the hydrogen and 373 ring is outside the extent of the nebular rings, and the inner part of the nebular ring is more intense than the outer part.

The Hα ring is isolated excepting on the north edge, where it strikes the nebular ring. The 373 ring is isolated excepting for the faint 387 and 345 rings, which interfere with it very little. These nearly isolated images are identical and show a striking amount of detail. Instead of the interlacing circles supposed by KEELER, the nebula appears more like a helix or single branched spiral of four loops. It is likely that much of the stronger detail is due to the loops of the spiral crossing in projection. The streams are not smooth, but coarsely granular. On the north side one loop is far inside the others, all three of which appear as one at this point. The supposed image of the central star observed by VON GOTHARD* and PALMER† is probably due to the effect of the continuous spectrum of the star crossing the 373 image of this innermost loop. The innermost loop on the south side appears to terminate abruptly at the west end of the nebula; unless, indeed, the most northerly bar inside the ring is a continuation of it. Whether or not this is the case cannot be determined on account of the presence of the north edge of the 387 ring. The fact that more detail is shown in the monochromatic images than in a direct photograph points to a difference in detail in the various rings. There is a slight trace of continuous spectrum; this may be

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†L. C.

so distributed as to blur the direct image. Of course this continuous spectrum may be due, as pointed out by PALMER, to weak bright lines distributed throughout the length of the spectrum.

It would be of great interest to photograph this nebula with an instrument giving about the same sized rings, but having considerably greater angular dispersion, so that the images of the chief nebular lines would be separate.

MOUNT HAMILTON, December 10, 1910.